

**EFFECT OF MOISTURE LEVEL TO AC BREAKDOWN VOLTAGE OF PFAE
BASED NANOFLUIDS**

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**A thesis submitted in fulfillment
of the requirements for the degree of Bachelor of Electrical Engineering (Industrial
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2015

“I declare that this report entitled “*Effect of Moisture Level to AC Breakdown Voltage of PFAE Based Nanofluids*” is the results of my own research except as cited in references. The report has not been accepted for any degree and is not currently submitted in candidature of any other degree.”

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For my family who always give me strength and encouragement during this time and my beloved friends that always be there when needed and give me a support. May Allah bless each one of you always.

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ABSTRACT

Power transformer in high voltage application is important part of electricity generation and transmission network. Hence, it needs a proper insulation and cooling system during operation. During transformer operation, insulation oil performance in term of breakdown voltage is affected by moisture that exists in the oil. Due to this moisture, the electrical characteristics of the insulating oil must be improved to avoid failure of power transformer due to low breakdown voltage. So, this study will be conducted to investigate the influence of nanoparticle dispersed in natural oil with water to breakdown voltage value. The objective this study are to prepare nanofluids by mixing conductive nanoparticles and water into natural oil, to setup a breakdown voltage test apparatus purposely used for liquid insulation test, and to determine and analyses the breakdown voltage level of nanofluids in concerned. In this study, electrical properties testing were carried out in term of breakdown voltage test. The test were conducted under moisture stress until of 0.20 ml, at intervals of 0.05 ml. The nanofluids insulating oil and Palm Fatty Acid Ester (PFAE) oil was through vacuum drying oven process for 72 hours before the breakdown voltage testing. Another addition is to study the breakdown voltage of nanofluids insulating oil under moisture stress. Result from the breakdown voltage test, the performances of nanofluids were carried out of the increasing the breakdown voltage and under moisture stress of nanofluid insulating oil based. Hence, the nanofluids can improve the breakdown voltage and good performances under moisture stress.

ABSTRAK

Pengubah kuasa dalam aplikasi voltan tinggi adalah bahagian yang penting dalam penjanaan dan penghantaran rangkaian elektrik. Oleh itu, ia memerlukan penebat dan sistem penyejukan yang betul semasa beroperasi. Semasa pengubah kuasa beroperasi, prestasi minyak penebat dari segi tahap ketahanan voltan dipengaruhi oleh kelembapan yang wujud dalam minyak. Oleh kerana kelembapan ini, ciri-ciri minyak penebat perlu dipertingkatkan bagi mengelakkan kegagalan pengubah kuasa mengalami voltan rendah. Oleh itu, kajian ini akan dijalankan untuk menyiasat pengaruh nanopartikel dicampur dalam minyak semulajadi dengan air untuk ujian nilai voltan kerosakkan. Objektif kajian ini adalah untuk menyediakan nanofluids dengan mencampurkan nanopartikel konduktif dan air ke dalam minyak semula jadi, untuk menyediakan alat ujian voltan kerosakkan untuk tujuan ujian penebat cecair, dan untuk menentukan dan menganalisis tahap voltan kerosakkan nanofluids. Dalam kajian ini, ujian sifat elektrik telah dijalankan dalam tempoh ujian voltan kerosakan. Ujian ini dijalankan di bawah kesan kelembapan sehingga 0.20 ml, pada selang 0.05 ml. Minyak penebat nanofluids dan Palm Fatty Acid Ester (PFAE) minyak melalui proses vakum pengeringan selama 72 jam sebelum ujian voltan kerosakan dijalankan. Selain itu, ujian tambahan adalah untuk mengkaji perbandingan voltan kerosakkan antara nanofluids dan minyak PFAE baru di bawah kesan kelembapan. Keputusan daripada ujian voltan kerosakan, prestasi nanofluids telah dijalankan untuk meningkatkan voltan kerosakkan dan di bawah kesan kelembapan antara nanofluids dan minyak PFAE baru. Oleh itu, nanofluids boleh meningkatkan voltan kerosakkan sementara PFAE baru menunjukkan persembahan yang baik di bawah kesan kelembapan.

TABLE OF CONTENTS

ABSTRACT	ii
ABSTRAK	iii
TABLE OF CONTENTS	iv
LIST OF FIGURE	vii
LIST OF TABLE	ix
Chapter 1	1
Introduction	1
1.1 Research Background	1
1.2 Problem Statement	2
1.3 Objective	2
1.4 Scope of Work	3
1.5 Contribution of Research	3
Chapter 2	4
Literature Review	4
2.1 Introduction	4
2.2 Theory and Basic Principal	4
2.2.1 Insulating Oil	5
2.2.2 Nanoparticle	5

2.2.3	Dielectric Strength	7
2.2.4	Water Content in Transformer Oil	8
2.2.5	Preparation of Nanofluid	9
2.3	Review of Previous Related Works	9
2.4	Summary of the review	12
Chapter 3		14
Design Methodology		14
3.1	Introduction	14
3.2	Principles of The Method	14
3.3	Methodology	15
3.3.1	Flowchart	15
3.4	Method of Experiment and Data Collection	18
3.4.1	Preparation of Nanofluids	19
3.4.2	Water Content into Oil	29
3.4.3	Setup Breakdown Voltage Test Apparatus	31
3.5	Timeline of Research Development (Gantt Chart)	38
3.6	Milestone Research	40
Chapter 4		41
Result and Discussion		41
4.1	Introduction	41
4.2	Result	41

4.2.1	Preparation of Nanofluids	42
4.2.2	Breakdown Voltage	42
4.3	Analysis	44
4.3.1	Preparation of Nanofluids	45
4.3.2	Breakdown Voltage	46
Chapter 5		51
Conclusion and Recommendation		51
5.1	Conclusions	51
5.2	Recommendations	52
References		53

LIST OF FIGURE

Figure 2. 1 : (a) 20 nm of diameter nanoparticle, (b) 45 nm of diameter nanoparticle, (c) 80 nm of diameter nanoparticle, (d) image corresponding to (b) [10].....	6
Figure 2. 2 : Breakdown Voltage Tester Kit. [6]	7
Figure 2. 3: 2.5mm gap electrodes in breakdown voltage tester [6].....	8
Figure 2. 4: The AC breakdown voltage [7].	10
Figure 2. 5: The breakdown voltage for pure oil and mix with nanofluids (Fe ₃ O ₄) [11].	11
Figure 2. 6: The breakdown voltage for pure oil and nanofluid (TiO ₂) [11].	12
Figure 3. 1: Flowchart of implementation the breakdown voltage test.	16
Figure 3. 2: Iron Oxide, Fe ₃ O ₄ Nanopowder.	19
Figure 3. 3: Nanoparticles (Fe ₃ O ₄).	20
Figure 3. 4: Flowchart for preparing of nanofluids.....	21
Figure 3. 5: Weight the nanoparticles.	22
Figure 3. 6: Measure oleic acid.....	23
Figure 3. 7: Measuring two litter palm oil.	24
Figure 3. 8: Put in the nanoparticles into palm oil.	25
Figure 3. 9: Drop out the oleic acid.	25
Figure 3. 10: Ultrasonic Treatment Process.....	26
Figure 3. 11: Probe diameter 40 mm, approx., 100 mm long.	27
Figure 3. 12: The setting of 50% cycle and amplitude.	27
Figure 3. 13: Vacuum drying Oven Process.	28
Figure 3. 14: Setting temperature at 70 0C.	28

Figure 3. 15: Setting time for 72 hours (4320 minutes).....	29
Figure 3. 16: Fill water into nanofluids.	30
Figure 3. 17: OTS60PB Portable Oil Test Set.	31
Figure 3. 18: Charging the battery.	32
Figure 3. 19: AUTOSOL.	33
Figure 3. 20: Clean the electrode using AUTOSOL.....	33
Figure 3. 21: The electrode after cleaned.....	33
Figure 3. 22: Rinsing the beaker with the oil sample.	34
Figure 3. 23: Loading the test vessel.	35
Figure 3. 24: Switch ON the oil test set.	36
Figure 3. 25: Select the IEC 156 standard.	36
Figure 3. 26: Select START button.	37
Figure 3. 27: The test begins.....	37
Figure 3. 28: Breakdown voltage result.....	38
Figure 4. 1: Preparation of Nanofluids (a) Before preparation (b) After preparation.....	42
Figure 4. 2: The differences during ultrasonic treatment process (a) Before treatment (b) During treatment.....	45
Figure 4. 3: The physical changed (a) Before treatment (b) After treatment.	46
Figure 4. 4: Bar chart of breakdown voltage PFAE and Fe ₃ O ₄ Nanofluids.	47
Figure 4. 5: Graph of Comparison Fe ₃ O ₄ Nanofluids and PFAE oil.....	48
Figure 4. 6: Graph of Average breakdown voltage of PFAE oil and Fe ₃ O ₄ nanofluids under moisture effect.	49

LIST OF TABLE

Table 3. 1: Water into nanofluids.	30
Table 3. 2: Gantt chart.	39
Table 3. 3: Key Milestone.....	40
Table 4. 1: The breakdown voltage of PFAE and Fe ₃ O ₄ nanofluids.....	43
Table 4. 2: The breakdown voltage under moisture effect.	44

Chapter 1

Introduction

1.1 Research Background

Power transformer in high voltage application is important part of electricity generation and transmission network. Hence, it needs a proper insulation and cooling system during operation. Mineral oil in power transformer serves as insulation liquid and as a coolant for the transformer. During transformer operation, insulation oil performance in term of breakdown voltage is affected by moisture that exists in the oil. Due to this moisture, the electrical characteristics of the insulating oil must be improved to avoid failure of power transformer due to low breakdown voltage. In recent years, nanofluids have been developed to improve both the breakdown voltage and insulating properties of mineral oil [1]. A nanofluid is a nanotechnology based heat transfer fluid, in which small amount of nano-sized materials (nanoparticles, nanofibers, nanotubes, nanowires, nanorods, or nano sheet) is stably suspended in a traditional heat transfer fluid such as mineral oil, water and ethylene glycol [2]. It shows that nanofluids display enhanced thermal properties, such as thermal conductivity and heat transfer coefficient, compare to their respective base fluids [3]. Up to recent years,

studies of nanofluid and its heat transfer capability are plentiful. However, research on the electrical characteristics of mineral oil based nanofluids is still limited [4][5][6]. With improves properties, nanofluids may help minimizing the size of HV components. Thus, in this study, the effect of nanoparticles dispersed in mineral oil with water to breakdown voltage will be carried out.

1.2 Problem Statement

The moisture content in the transformer oil is affecting the alternating current (AC) breakdown voltage of oil-immersed power transformer. Low breakdown voltage of insulating oil is one of factor towards transformer failure because if insulating oil is broke down, there will be no appropriate insulation left for the power transformer. Hence, normal transformer operations are effected. So, this study will be conducted to investigate the influence of nanoparticle dispersed in natural oil with water to breakdown voltage value.

1.3 Objective

The objectives of this study are to:

- i. To prepare nanofluids by mixing conductive nanoparticles and water into natural oil.
- ii. To setup a breakdown voltage test apparatus purposely used for liquid insulation test.
- iii. To determine and analyse the breakdown voltage level of nanofluids in concerned.

1.4 Scope of Work

The scopes of this study are:

- i. Types of nanoparticles used are conductive nanoparticles (Iron oxide, Fe_3O_4) only.
- ii. Type of natural oil used is Palm Fatty Acid Ester Oil (PFAE), a Malaysian product.
- iii. Alternating current (AC) high voltage testing, a breakdown voltage tests according to IEC 156/1995 standards under moisture effect.

1.5 Contribution of Research

This research is for insulating oil that can contribute for generation, transmission and distribution system network. This research is to prove that nanoparticle can improve the breakdown voltage of insulating oil. Thus, nanoparticle is studied for contribution to improvement of insulating oil.

Chapter 2

Literature Review

2.1 Introduction

This chapter contain a literature review that related to this research. All the information that needed to implement the experiment is studied and will show in this chapter. The main information that contain in this chapter is about nanoparticles, insulating oil and breakdown voltage. Furthermore, the previous work that researcher have been studied also explain in this chapter included the result that they have studied in past.

2.2 Theory and Basic Principal

The transformer oil for high voltage insulation has extensive research work aimed to enhancing both its breakdown voltage and characteristics. Moisture that exists in the transformer oil will affect the breakdown voltage and is possible transformer failure can be damage the transformer. The transformer oil that effect by moisture was in research to know

the breakdown voltage and improvement to increase the breakdown voltage. In this research, the innovative work to increase the breakdown voltage is the development of dielectric nanofluids. These nanofluids materials are manufactured by adding nanoparticle and disperse from powder into liquids. The breakdown voltage or dielectric strength was improved by adding nanoparticle into natural oil and water as moisture in the transformer oil. Nanoparticle is selected with different type were added into transformer mineral oil and water.

2.2.1 Insulating Oil

Transformer oil that has been use in power transformer for high voltage application is also called insulating oil. The reason why the transformer oil is same meaning with insulating oil because it was obtained by subsequent treatment of crude petroleum and fractional distillation processes. Four main proposes serves by transformer oil in electrical power transformer which is for liquid insulation and dissipates heat of the transformer or as a coolant for the transformer [6]. On the other function of transformer oil is to preserve the core and winding that is fully immersed inside oil. Besides that, the function of transformer oil is to prevent from direct contact of atmospheric oxygen with cellulose made paper insulation of winding, which is susceptible to oxidation [6].

2.2.2 Nanoparticle

A nanoparticle is defined as microorganism particle and microscopic particle. A nanoparticle is easy to understand by compare the size of the particle. Another meaning of

nanoparticle is ultrafine particle. The size of the nanoparticle is 1-100 nanometers (nm) [8] [9].

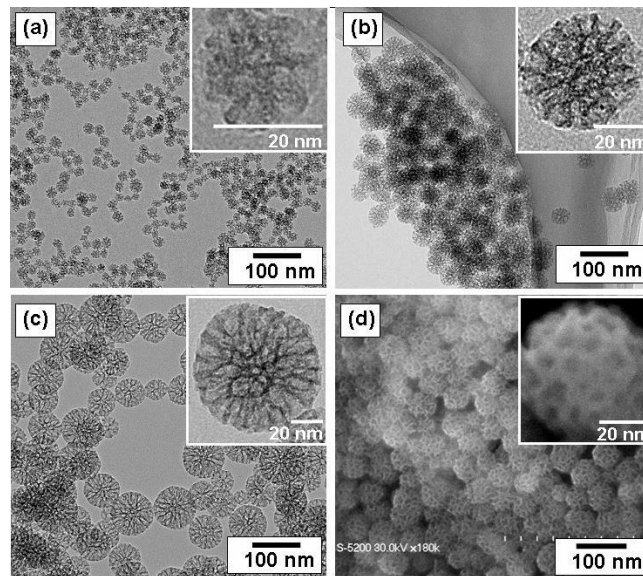


Figure 2. 1 : (a) 20 nm of diameter nanoparticle, (b) 45 nm of diameter nanoparticle, (c) 80 nm of diameter nanoparticle, (d) image corresponding to (b) [10].

In industry application, nanoparticle has different physical and chemical properties in their bulk metal. The nanoparticle can serve as a bridge between bulk materials and atomic or molecular structures. Generally, a bulk material must have same quantity properties if the nanoparticle is included. Nanoparticle can be dispersed or embedded with the liquid or bulk material. The change of the properties of materials is size influenced by nanoscale. Nanoparticles have a very high surface area to volume ratio [8]. With a high surface area this will force for diffusion especially at elevated temperature. Sintering can serve for low temperature and shorter time scales than for large materials [8]. This statement is not affect the density of the original product even nanoparticle influence the materials properties. A large surface area to volume ratio reduces the melting temperature of nanoparticle [8]. The types of nanoparticle that have been used in electricity system are conducting nanoparticle,

semiconducting nanoparticle and insulating nanoparticle. Recently, nanoparticle research was enhancing in different application which is in optical, biomedical and electronic fields.

2.2.3 Dielectric Strength

Dielectric strength in power transformer is also called breakdown voltage. Breakdown voltage is the maximum voltage can prevent the transformer failure that can be damage the insulating oil. It measured by maximum voltage that can be prevent and sparking between two electrodes immersed in the oil which is with separated by specific gap [6]. Moisture that exists in the transformer oil can reduced the value of breakdown voltage. To measure the breakdown voltage in lab or at site, a portable breakdown voltage measuring kit is available in market and used nowadays. The test needs the insulating oil and kept in a beaker then put the electrode for the test. There are standard that must be followed to valid the test.



Figure 2. 2 : Breakdown Voltage Tester Kit. [6]



Figure 2. 3: 2.5mm gap electrodes in breakdown voltage tester [6].

To begin the test, applied the voltage between the electrodes and increase the voltage steadily. If the sparking can be seen at the electrode, the breakdown voltage of the transformer oil is achieved. So, the value breakdown voltage is satisfied. Generally, this test is repeat 3 to 6 time in same sample of oil and the average value is taken [6]. Breakdown voltage is important in transformer oil because to check of health of oil and moisture that exists in the oil. The breakdown voltage test of transformer oil is to confirmed that the oil is safely be used in the transformer operation.

2.2.4 Water Content in Transformer Oil

Moisture or water that exists in the power transformer oil is unwanted materials that affected the dielectric properties of oil. The paper insulation and winding of transformer is influenced by water that content in transformer oil. In nature, paper is highly hygroscopic [6]. Water in oil will absorbed by paper and affected the insulation properties as well as reduced its lifetime. In operation condition, transformer oil become hotter and makes the solubility of water in oil increases. Then, the paper will releases water and increase the moisture content in transformer oil. It is very important the temperature of the oil at the time of taking sample for

test [6]. Parts per million (ppm) is a units that measured water content in oil [6]. Recommended by IS-335(1993), up to 50 ppm is allowed water in oil [6]. But in this research, the water will measure by percentages (%).

2.2.5 Preparation of Nanofluid

From another researcher, they state there are two method for disperse the nanoparticle into mineral oil [11]. There are one-step method and two-step method. Most of them prefer used the two step method for mixing the nanoparticle and natural oil. In recent years, the two step methods are widely used than one step method because of their low cost [11]. Besides that, the two step methods have a large surface area and the high surface activity of the nanoparticle. For mixing the nanoparticle with natural oil, needs to improve the nanoparticle dispersion stability in the oil. For preparation nanofluids, mixing nanoparticle with oleic acid shows the good feedback for long term dispersing stability in transformer oil at room temperature over period of 24 months [11]. Furthermore, it is challenging for preparation nanofluids for use in industrial power transformer as well as good for long term dispersing stability. So, in this experiment will use two step method for nanofluids preparation.

2.3 Review of Previous Related Works

Research on nanotechnology is enhancing nowadays to improve the dielectric strength or breakdown voltage especially in power transformer oil. From time to time, some improvement is needed to a better system and reduces the error and failure in the system. In this research is focus on nanotechnology and transformer oil. Before this study is

implemented, there are some research is conducted by some researcher. In their research, they only focus the scope of the research and specific on their study and related in this study. Next, the research and experiment that previously done and can related by effect of nanoparticle on the electrical characteristic of insulating oil.

From article “AC Breakdown Voltage and Viscosity of Mineral Oil based silicon oxide (SiO₂) Nanofluids” (2012), the research is test the breakdown voltage as well as effect of nanofluid to the mineral oil. In their research, they use SiO₂ as a nanoparticle and mix with the mineral oil. The size between 10 nanometer (nm) and 20 nm of SiO₂ nanoparticle are used in this works. The mass fraction between 0.005% and 0.02% is the investigated nanofluids. They study the influence of nanoparticle centration and moisture content on the breakdown voltage. The transformer oil that has been used in their experiment is Diala S3ZXIG. From this article also explain the viscosity test. They test the effect of nanoparticle to the viscosity and effect viscosity to the breakdown voltage.

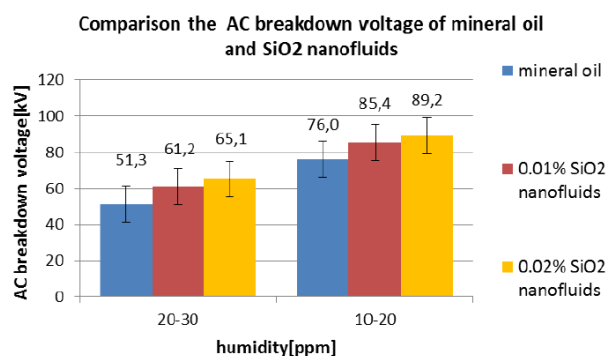


Figure 2. 4: The AC breakdown voltage [7].

Figure above shows the result of breakdown voltage test and comparison between affected by nanofluids and the original mineral oil. Its show positive feedback and the rated

of breakdown voltage is increases. So, the oil can works more in high voltage application in transformer oil.

According to Institute of Electrical and Electronics Engineers (IEEE) Electrical Magazine, the article of “Recent Progress in Nanofluids Based on Transformer Oil: Preparation and Electrical Insulation Properties” there are related works in this study. They are study preparation of nanofluids based on transformer oil and analyse the electrical insulation properties. In their study, the preparation of nanofluids is divided into three groups. First group is conducting nanoparticle as well as they disperse with nanoparticle type of magnetite (Fe_2O_3) and zinc oxide (ZnO). Second group is semiconducting nanoparticle which is the type is titanium dioxide (TiO_2), copper (II) oxide (CuO) and copper (I) oxide (Cu_2O). The last group is insulating nanoparticle and the type used is aluminium oxide (Al_2O_3) and silicon oxide (SiO_2). The reason the mechanism of nanoparticle can increase the breakdown voltage of the transformer oil is still not fully understood. In their research, there are two step methods that have been used in the experiment.

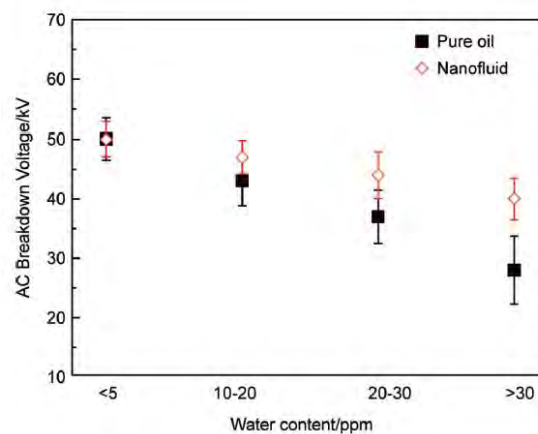


Figure 2. 5: The breakdown voltage for pure oil and mix with nanofluids (Fe_3O_4) [11].